

CHAPTER 4

QUALITY CONTROL AT THE STATIONS

4.1 Introduction. Quality control of the sounding data at the observing site must be accomplished by an effective mix of automated and observer-initiated procedures. The data quality control information given herein is mostly appropriate for automated processing; however, observers must be capable of monitoring the automated processing and exercising final judgement of the quality of the sounding data before it is transmitted and archived.

Determining the quality of rawinsonde data can be a subjective process. In many cases it is a straightforward matter for an automated scheme to distinguish erroneous from satisfactory data. This Chapter provides guidelines for determining if the data are satisfactory, erroneous, or doubtful. These guidelines are based on research studies, known radiosonde sensor limitations, and what is physically possible to occur in the atmosphere.

This Chapter describes data anomalies that may be encountered when analyzing radiosonde pressure, temperature, humidity, and wind measurements. These data anomalies are defined as erroneous or doubtful data. Data determined to be erroneous *shall* be eliminated and considered as missing data. Data suspected to be erroneous, but not determined to be so, *shall* be reported as doubtful. (See Appendix E-II.2.9 and Table 0421.)

4.2 Pressure Anomalies. Because measurements of temperature, humidity, and wind are expressed in the coded message in terms of pressure, and because the relationship between pressure and geopotential height involves an integration with pressure (Appendix D), critical dependence is placed upon a satisfactory measurement of pressure.

The following sections describe the causes and identification of in-flight pressure profile distortions, and the procedures that *shall* be followed if these anomalies are observed. Radiosonde pressure data anomalies may be caused by ground system failure, a faulty pressure sensor, or atmospheric phenomena affecting the ascension rate of the flight train.

4.2.1 Anomalies Caused By Pressure Sensor or Radiosonde Failure.

4.2.1.1 Surface Pressure Discrepancy. It is important to determine if the pressure sensor is operating correctly as soon as possible after the balloon has been released. One method for checking this is to determine the discrepancy between the surface pressure observation (obtained from instrumentation other than the radiosonde) and the first few pressure readings from the radiosonde after release. Since the exact method is dependent on the radiosonde being used, agencies *should* develop specific techniques to check for surface discrepancies and the appropriate tolerances. Discrepancies that exceed the tolerance *should* result in a system message requesting the observer to verify that the surface pressure was entered correctly, since the discrepancy may be due to incorrect entry of observed surface pressure instead of an actual pressure

sensor failure. If the observer determines that the radiosonde pressure sensor is at fault and the discrepancy exceeds agency tolerances, the flight *shall* be terminated.

4.2.1.2 Missing Pressure Data. Pressure sensor or ground system failures are to be suspected when there is loss of signal which causes a number of sampling points to be missing. If more than 10 minutes of contiguous pressure information is missing, a sufficient number of standard levels (Section 5.2) will be lost that the sounding will be without value and the sounding *shall* be terminated.

4.2.1.3 Constant Pressure Values. Pressure values that become constant with time are indicators of either sensor defects or balloon failure. The flight *shall* be terminated at the data point where the constant values began if, over a 5-minute period, the pressure does not change.

4.2.1.4 Rapidly-Changing or Biased Pressure Data. A faulty or leaking pressure cell causes the radiosonde to report pressures that are inconsistent or rapidly changing with time, rather than exhibiting a smooth and gradual minute-by-minute change. This problem may be especially apparent at pressures less than 100 hPa. Analysis or examination of a pressure-versus-time plot can help determine if this is occurring.

The observer should be aware that a leaking pressure cell is occurring if pressure levels are reached much earlier in the flight than is typical. For example, the 10 hPa level may be reached at 60 minutes instead of the usual 90 to 100 minutes (for nominal ascent rates). A serious effect of pressure-bias errors is that higher or lower (i.e. biased) temperatures are chosen along with the erroneous pressures, causing large changes (e.g. from previous soundings) in geopotential heights calculated for the pressure levels.

A pressure sensor that leaks slowly will cause erratic changes in ascension rate and height, resulting in a pressure versus time profile resembling a staircase. A pressure sensor that leaks abruptly will cause a rapid decrease in the reported pressures, resulting in a rapid, unrealistic increase in reported ascension rate and height.

Flights containing a leaking pressure sensor provide data that are no longer representative of the atmosphere and *shall* be terminated at the last usable pressure observation before the leakage began. When it cannot be exactly determined at what point the pressure cell began leaking, the flight *shall* be terminated at the last pressure where it is known the data are valid.

4.2.2 Anomalies Caused By Balloon.

4.2.2.1 Balloon Burst. Balloon burst is identified when the pressure changes from decreasing to increasing for at least two minutes at pressures less than 400 hPa and for five minutes at pressures greater than or equal to 400 hPa.

4.2.2.2 Floating Balloons. A balloon with a small hole or one weighed down by icing may stop rising and float. A floating balloon is identified by little or no change in pressure over time. The flight *shall* be terminated at the data point where the constant values began if over a 5-minute period the pressure stays constant or the ascent rate slows to 100 meters per minute or less.

4.2.3 Anomalies Caused by Atmospheric Events. Large changes in ascent rates may result from a variety of atmospheric events, including downdrafts or updrafts inside a thunderstorm and near strong winds aloft (such as the jet stream), icing on the balloon, or heavy rain.

Flights taken near or inside thunderstorms have a characteristic pressure -versus- time profile. The profiles are distorted, not because of a pressure sensor problem, but because of changes in the ascension rate of the balloon. The ascension rate-versus-time profile may show several periods of differing ascension rates. A reduced rate of pressure (height) change with time is likely due to the radiosonde being in a downdraft. On the other hand, an increased rate of pressure change with time likely reflects the influence of an updraft.

The cause of observed pressure anomalies *should* be determined. Other weather observations (e.g., surface, radar, pilot reports) can provide information to help. Erratic pressure profiles caused by weather conditions usually happen at pressures greater than 400 hPa, where ice accumulation on the flight train, strong updrafts/downdrafts, and heavy rain most likely occur.

If it is determined that the ascension rate changes are due to meteorological events, the flight *shall not* be terminated. However, if pressure sensor or general radiosonde failure is determined to be causing the anomaly the flight *shall* be terminated at the last satisfactory pressure observation.

4.3 Temperature Anomalies. Radiosonde temperature anomalies may be caused by ground system failure, radiosonde defects, or atmospheric events. The following sections describe typical temperature data anomalies and the procedures that *shall* be followed if they are observed. Whenever any portion of the temperature record is classified as doubtful, the flight *shall* continue provided that no more than three minutes of doubtful data occur at pressures greater than 700 hPa. If more than three minutes of data are doubtful, the flight *shall* be terminated and another flight made. Strata with doubtful data *shall* be encoded in the rawinsonde message in the proper group (see Appendix E-II.2.9 and Table 0421).

Since relative humidity calculations require temperature data, relative humidity data *shall* be defined as doubtful if the temperature data are doubtful.

4.3.1 Anomalies Caused By Temperature Sensor or Radiosonde Failure.

4.3.1.1 Missing Temperature Data. Ground system, temperature sensor, or radiosonde defects are to be suspected when there is loss of signal or sensor dropouts. Whenever a portion of missing data is followed by a satisfactory record, the computations *shall* be continued, provided the total amount of missing data does not exceed the limits provided in Table 3-1. If any of these limits are exceeded, the flight *shall* be terminated at the pressure value where the missing data began.

4.3.1.2 Constant Temperature Values. Constant temperature values with time (values changing by less than 0.5°C) can result immediately after release if the temperature sensor is damaged in some way. For instance, during release in high winds the radiosonde sometimes strikes the ground, damaging the temperature sensor. Radiosonde defects can also cause this effect to occur during later portions of the flight.

If temperature values change by less than 0.5/C over a 5-minute period from surface to 400 hPa the erroneous temperature data during the time period *shall* be deleted and the flight terminated. From 400 hPa to termination, temperatures changing less than 0.5/C over a 10-minute period *shall* necessitate the termination of the flight at the point where the constant temperatures began.

4.3.1.3 Erratic Temperatures. Abrupt shifts in the temperature data from one data point to the next can be caused by temperature sensor defects, radiosonde defects, or interference in the radiosonde signal and *shall* be deleted. The temperature profile may be abruptly shifted either toward higher or lower values from the normal trend, causing a shallow layer of superadiabatic lapse rates (see Section 4.3.2) and inversions to appear. Sometimes the shift may revert back to the original trend at a later point in the observation. Automated procedures for identifying erroneous data involve knowledge of the response time

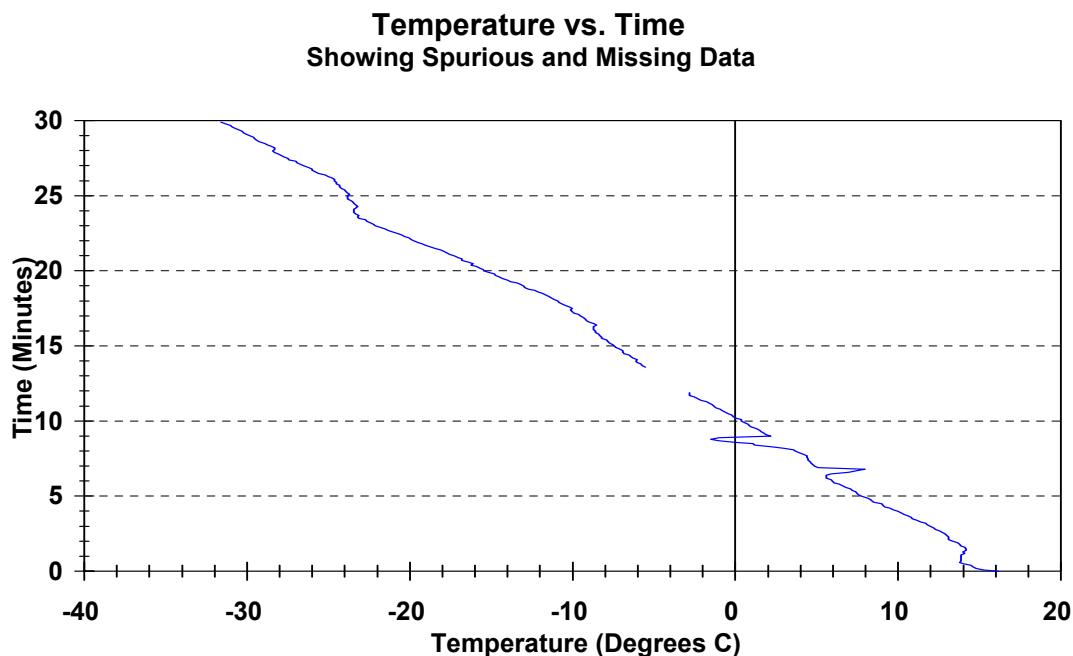


Figure 4-1. Plot of temperature -versus- time, showing incidents of missing and erroneous data.

of the temperature sensor. If the temperature change per unit of time is greater than the capabilities of the sensor, the data are erroneous and *shall* be deleted. Figure 4-1 illustrates some occurrences of some missing and erroneous temperatures.

4.3.1.4 Temperature Biases. Identifying temperature readings throughout a flight that are biased too high or low can be difficult. One way to check is for the observer to have knowledge of the

temperature structure made throughout the previous sounding. If significant changes in this structure are observed that cannot be attributed to changes in atmospheric structure the sounding **should** be terminated.

4.3.2 Superadiabatic Lapse Rates. Superadiabatic lapse rates are defined as a temperature decrease with height greater than 9.77/C/km or any decrease in potential temperature with increasing height. Such indicated lapse rates might be associated with temperature sensor shifts, pressure sensor failures, or outliers resulting from signal noise. They may also occur naturally under certain atmospheric conditions. It is not uncommon for these lapse rates to occur in thin layers near the ground owing to surface heating from the sun; they are not typically found above the surface layer. Thunderstorms, atmospheric gravity waves, or upper-tropospheric fronts could, for example, be a cause of indicated super-adiabatic lapse rates.

Occasionally a thick layer exhibiting a superadiabatic lapse rate occurs when the sensor becomes covered with moisture. This is known as the "wet-bulb effect" and results when water or ice on the temperature sensor evaporates or sublimates, cooling the sensor. In general, high relative humidities occur with the wet-bulb effect, followed by a sharp drying trend. A characteristic temperature inversion also is present at the level of drying. The inversion is due to the sensor's recovery from the cooling of evaporation or sublimation.

Often a super-adiabatic lapse rate results at the beginning of the sounding because the surface temperature observation, taken with equipment other than the radiosonde, is significantly warmer than the first radiosonde temperature measurement a few seconds after release. The resulting profile may be real, owing to daytime heating from the sun; it may be erroneous, owing to radiosonde defects, poor siting of the surface observation equipment (e.g., too far from the release point) or differences in accuracy of both systems, since temperature sensors differ significantly. If strong near-surface profiles (more than 1/K decrease in potential temperature) frequently occur at a site, siting problems or problems with the observing equipment are likely the cause and **should** be corrected.

Layers of temperature data showing super-adiabatic lapse rates **shall** be categorized as valid if the decrease in potential temperature in the layer does not exceed 1.0/K. If the lapse rate exceeds this value, the temperature data in the layer are not realistic [Ref. 4.] Data **shall** be deleted if the potential temperature decreases by more than 1.0/K over any stratum or interval. If the temperature reverts back to the original trend, the data **should** be carefully examined to determine if the shift is real or erroneous. If the observer suspects it is erroneous those data **shall** be flagged as doubtful.

4.4 Relative Humidity Anomalies. The detection of relative humidity (RH) data anomalies is difficult since humidity data do not always decrease with height as does pressure. Some anomalies, caused by sensor failure, improper sensor acclimation to ambient conditions, or atmospheric events, can be readily identified and are described below. Even if any RH data are missing, geopotential height calculations **shall** be carried out.

4.4.1 Missing Relative Humidity Data. Ground system failure, RH sensor defects, or other radiosonde defects can cause missing RH data. Situations when doubtful data occur are described in the following sections. If the agency considers the RH data of decided importance, a stratum of missing or doubtful RH data exceeding the limits in Table 3-1 would require another release.

Since relative humidity sensor conversion algorithms require temperature data, relative humidity data **shall** be defined as doubtful if the temperature data are doubtful.

4.4.2 Erroneous RH Data. Erroneous RH data are much more difficult to spot than erroneous temperature data, although they may occur for the same reasons. However, if signal quality is marginal or better, the erroneous data may be identified if the relative humidity profile shows points that are significantly different (appear as a data "spike" in a RH versus time plot) from the data above and below them. This is easy to recognize if the suspect data points occur in a thick layer of humidities that are of equal value. Another method used by automated checking procedures for determining erroneous RH data is through knowledge of the response time of the humidity sensor: if the RH change per unit of time is greater than the capabilities of the sensor the data are erroneous.

4.4.3 RH Data Biased Too High or Too Low. Sometimes during a flight all or most of the RH values reported by the radiosonde may appear biased too high or low. This anomaly is likely caused by one or a combination of the following:

- Damaged sensor. A damaged sensor may occur during shipment from the factory, during observer prerelease procedures, or during release if the radiosonde strikes another object. Observers **shall** take extreme care not to damage the sensor during preflight procedures. Depending on the type of radiosonde used, a damaged sensor can cause the humidity to read too high or too low. For example, a scratch or fingerprint on a carbon element can cause RH profiles to be biased too high.
- Lack of a sensor. Some radiosonde types require the observer to place the humidity sensor (e.g., a carbon element) into the radiosonde. If the observer fails to do this, an "open circuit" results, causing the RH data to be near 100% throughout the flight.
- Sensor wetting or icing. A sensor that becomes wet from precipitation or from passing through a thick layer of cloud may not recover and will report RH values biased too high for the remainder of the flight.
- Incorrectly calibrated sensor.
- General radiosonde failure.

During the flight, identifying RH biases can be difficult. However, high biases are likely occurring if more than 30 minutes of RH data are greater than 90%, or at least 15 minutes are greater than 80% from 400 hPa to flight termination. If this occurs, all relative humidity data greater than 80% **shall** be designated as doubtful.

RH values that are biased low can sometimes be identified if a thick layer of clouds is observed covering the entire sky, but the RH profile at the height of the clouds is too dry (less than 50% RH). If this discrepancy is observed at pressures greater than 400 hPa (the region of the troposphere where most clouds occur), all RH data at and above the height of the cloud ceiling **shall** be deleted.

4.4.4 Rapid Change in RH Immediately After Release. Occasionally the RH profile just above the surface exhibits an abrupt shift from the surface observation. This anomaly usually occurs when an

unventilated radiosonde is calibrated in a room where the temperature and RH are significantly different from what are observed at the release point. This effect is more likely to occur with radiosondes using carbon-element sensors positioned in a duct, and is caused by the RH sensors not being properly ventilated prior to release. This problem can be mitigated by having the observer hold the radiosonde outside and moving it up and down for 30 seconds so that air will pass through the duct and over the RH sensor.

Faulty or poor location of surface observing equipment can also cause this anomaly to occur. If this anomaly frequently occurs and inadequate radiosonde ventilation is not the cause, problems with the surface equipment accuracy or location with respect to the release point may be the cause and the equipment *should* be checked.

4.5 Wind Anomalies. Detecting wind data anomalies is difficult since wind speed and direction can change significantly with height and/or time. However, the following sections provide descriptions of how the ground tracking system and/or radiosonde can cause missing or erroneous winds. Guidelines for identifying and handling such data follow: additional instructive information on upper-air wind-finding can be found in Ref. 6, Chapter 12, and Ref. 8.

4.5.1 Anomalous Wind Data From Radio Direction Finding (RDF) Systems. Anomalous winds from RDF tracking systems result from incorrect determinations of the radiosonde's position that are due to errors in one or more of the positioning parameters: elevation angle, azimuth angle, and range. Factors affecting the accuracy of position determination are discussed below.

4.5.1.1 Tracking on Antenna Side Lobes. The RDF antenna receives radiosonde radio signals in two distinct patterns, one associated with the main lobe and the other the side lobes. If the radiotheodolite system locks onto a side lobe instead of the main lobe, the position data are incorrect and tend to be very erratic with time. Wind data determined to be derived from side lobe tracing are in error and *shall* be deleted.

4.5.1.2 Noisy or Weak Signal. Anomalous angular data may result from signal interference (i.e., noise), weak or fading signals, or faulty ground equipment. This situation is most prevalent when elevation angles are below 12 degrees, but can occur at other angles as well. Sudden, abrupt changes in the elevation or azimuth angles of the antenna from one data point to the next are not realistic and are caused by signals that are too weak to supply the ground receiver with an adequate reference or by the lack of tracking sensitivity in the ground equipment.

Another type of elevation angle anomaly occurs when the elevation angles are greater than 12 degrees and at least 15 minutes of the observation have elapsed. In this case, erratic angles can be caused by equipment which is not operating properly, is tracking on a secondary lobe, or has undergone a signal loss. The result will be tracking errors that are in excess of predetermined tolerances in azimuth or elevation angles.

Erratic angles or spikes in the data caused by noisy or weak signals or ground equipment problems *shall* be "smoothed" or removed in accordance with the manufacturer instructions or individual agency guidelines.

4.5.1.3 Multipath Propagation and Limiting Angles. Multipath propagation causes the antenna to stay in one position for a short time and recover when it gets an adequate signal. This will cause the antenna to "bounce" and plots of the elevation angles with time look like steps, or waves, on the plots. This situation is most prevalent when elevation angles below 12 degrees are encountered and becomes increasingly pronounced as the elevation angles near 0 degrees. If multipath propagation is determined to be occurring, the anomalous data *shall* be deleted.

The limiting angle is the elevation or azimuth angle of the RDF antenna above or along the horizon below which the antenna cannot successfully track the radiosonde owing to multipath propagation. Generally, limiting angles are no less than 6 degrees from the horizon or obstructions (e.g., mountains or buildings) along the horizon. All computer systems associated with RDF systems *should* contain a data file of the limiting angles to identify limiting angles for the antenna. Whenever the elevation and azimuth angles are equal to or less than the limiting angles, the data *shall not* be used to calculate winds.

4.5.1.4 Transponder-Related Problems. RDF systems that use transponder radiosondes for obtaining slant range of the flight train may encounter the following problems:

Slant Range Shift. Shifts in the slant ranges result from noise or momentary power interruptions. Abrupt differences in the slant range values from minute-to-minute may indicate where the failure has occurred. It is likely that the ground equipment did not receive one of the one-half wavelength cycles from the radiosonde. Errors of this type *shall* be corrected in the radiosonde position data file.

Transponder Failure. The following are guidelines to determine when the transponder sonde has failed:

- If the slant range stops increasing for a period of 5 minutes or increases at a rate of less than 500 meters/minute and the corresponding elevation angles continue to decrease, the ranging has failed or the balloon has burst.
- If the slant range increases at greater than 2000 meters/minute for at least 5 consecutive minutes without a decrease in the corresponding elevation angles, the ranging has failed.
- If the elevation angles are exceeding the limiting angle threshold and the change of slant range between consecutive minutes becomes less than 100 meters, the elevation angle must begin increasing; otherwise, it has failed.
- If the height in meters (MSL) is greater than the acquired slant range (after shift correction), that minute *should* be considered invalid. If five consecutive minutes have been designated invalid, the transponder has failed.

When the radiosonde transponder has failed and slant ranges cannot be used, elevation angles *shall* be used in the processing of the position data file if they are above the limiting angle threshold.

4.5.1.5 Balloon Overhead. Under light or calm wind conditions near the surface or with shifting winds aloft, the radiosonde may track directly over the RDF antenna (i.e., elevation angles approach 90 degrees) and the ground equipment antenna system may not be able to continue tracking. In such cases, the antenna drive mechanism "locks up," requiring operator intervention to regain antenna tracking. When

the following conditions occur, the angular data may be in error and *should* be checked: the elevation angles are greater than 80 degrees within the first five minutes of the observation or the azimuth angles have changed by more than 100 degrees from one whole minute to the next for at least one of the elevation angles greater than 85 degrees.

In many instances, the RDF system software *should* detect this situation and automatically delete the wind data during the period of the lockup.

4.5.2 Anomalous Wind Data From NAVAID (LORAN or GPS) Systems. Unlike RDF systems, wind data obtained from LORAN or GPS tracking systems are not degraded by low elevation angle of the balloon flight train resulting from strong winds. Provided an adequate telemetry link is maintained between the balloon and the data processing ground station, NAVAID wind errors are not dependent on the distance between them. However, the availability and quality of LORAN and GPS wind data can be degraded by the following:

- poor maintenance of the ground equipment,
- strong electric fields in the vicinity of the radiosonde caused by thunderstorms or snowfall (this affects LORAN and VLF),
- radio interference, especially for radiosondes operating in the 400 MHz band,
- poor location of LORAN or VLF transmitters with respect to the release point (i.e., all transmitters are positioned within a limited azimuth angle or one transmitter located too close to the release point), or
- LORAN station or GPS satellite "signal" is lost immediately after balloon release.

4.5.3 Doubtful Wind Data. After the wind data have been processed from either the raw RDF or NAVAID data, a check *shall* be made to assess the validity of the data. Because of the variety of possible meteorological phenomena influencing the wind profile, it is difficult to determine if winds are erroneous or satisfactory. The following are some guidelines for identifying and handling doubtful wind data.

4.5.3.1 Missing Wind Data. The flight *shall* continue to termination regardless of the amount of missing, erroneous, or doubtful data. However, some agencies *may* set their own requirements for second releases.

4.5.3.2 Rapid Change in Winds Near the Surface. Immediately after release, a comparison *should* be made with the surface wind measuring equipment and the 300m wind measurement reported by the radiosonde. If the topography near the release point is generally flat and there is no low-level temperature inversion, surface winds at speeds over 15 knots are not expected to be significantly higher (10 knots or more) than the winds measured at 300m. If such a decrease is observed, the surface equipment may be out of calibration or the winds at 300m may be erroneous.

During a flight the winds may rapidly increase off surface. In many cases, this change in speed is real. However, wind speed increases of 40 knots or more between the surface and 300m are not likely to occur and such measurements may be erroneous.

Wind direction in the first 300m of the flight can shift through the layer more than 180 degrees. However, if the wind speed throughout the layer exceeds 20 knots and the wind direction shifts more than 90 degrees, the data may be in error.

4.5.3.3 Rapid Changes Above 300m. If rapid changes in wind speed or direction occur, the entire wind profile *should* be examined closely. The raw position data *should* be checked for validity and upper-air charts, aircraft observations, and/or wind forecasts *should* also be checked to determine if such winds are possible. Wind data determined to be erroneous *shall* be deleted.

Occasionally, the wind profile during the flight will show rapid changes in wind speed and direction over layers approximately 300 meters thick. If the winds are less than 20 knots in the layer, the rapid wind changes could be valid. However, if the wind speed changes more than 40 knots over a 300 meter layer the data may be in error, especially if the change occurred at altitudes where the jet stream winds are not located (generally below 8 km and above 15 km). Wind speeds that exceed 250 knots are not typical and may also be in error.

Wind profiles with wind speeds greater than 20 knots usually show a gradual change in wind direction at 300m increments. However, if the wind speed exceeds 20 knots in the layer and the wind direction changes more than 90 degrees, the wind data may be erroneous.

4.5.3.4 Flights Near and Into Thunderstorms. Thunderstorms may affect the validity of the flight position data. Typically, wind speed and direction change abruptly in and near thunderstorms, causing unusual wind profiles to appear. With RDF systems, erratic angles may also result from lightning causing radiosonde signals to drop out. High electric fields in and near the storms may cause NAVAID signals to drop out as well. If the observer determines that the flight train is in or near a thunderstorm, individual agency guidelines for processing the wind data *shall* be followed.